FIBER LASER ENGRAVING ON FLAT AND UNEVEN SURFACES

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Abstract: Laser engraving is a technology suitable for objects with diverse shapes and relief. It involves the removal of the top surface of the material through a precisely focused laser beam. This technology offers a wide range of design and personalization possibilities. The results of laser engraving are formed depending on several key factors, such as the composition and properties of the material, the power of the laser beam, and the speed and intensity of the process. In this context, the article examines the characteristics of engraving with fiber lasers, which are highly effective in processing materials such as leather, metal, and composite surfaces (ABS). A distinctive feature of laser engraving is its applicability to objects of various shapes and sizes, making the technology extremely flexible across different industries. The maximum object size and the printing area the machine can cover vary depending on the specific model and technical characteristics of the laser. The article explores results of engraving on flat and uneven surfaces, as well as objects with irregular shapes. Applying the laser beam at different heights can lead to changes in engraving intensity in the same area, attributed to the variety in the object's relief and the deviation of the beam from its optimal values. System settings requirements vary depending on the material, and the correct configuration leads to optimal results. While laser engraving provides limitless possibilities for creativity and personalization, attention to the correct settings is crucial. Improper application can result in detrimental outcomes and even the destruction of the object. Therefore, proper configuration and attention to detail are key to achieving successful and high-quality engravings. Fiber lasers find widespread application in industries such as metal engraving, where their high precision and efficiency make them a preferred choice. In the medical industry, they are used for marking instruments and manufacturing metal components. They are also applied in electronics, jewelry, and the production of promotional materials. This research significantly benefits stakeholders across diverse industries by advancing precision and versatility in material processing. The study's experience facilitate optimized configuration settings for different materials, ensuring stakeholders achieve intricate designs with utmost accuracy. The application of fiber lasers in metal engraving, medicine, electronics, jewelry, and promotional material production is underscored, showcasing the technology's adaptability to varied industrial needs. Stakeholders find cost-effective solutions through the enhanced efficiency of fiber lasers, reducing the necessity for additional processes. With a focus on engraving flat and uneven surfaces, the research expands creative possibilities for artists and designers, catering to the growing demand for personalized outcomes. The study establishes industry best practices, offering a valuable reference for stakeholders seeking to adopt or optimize laser engraving processes. Quality assurance is emphasized, minimizing errors and rework, while technological advancements in fiber lasers contribute to positioning stakeholders at the forefront of innovative and efficient material processing methods.
Keywords: laser engraving, flat and uneven surfaces, optimal values

1. INTRODUCTION

Laser technologies are used in many design and industrial fields (Dobler et. all 2013, Gopal et. all, 2023, He et. all 2022, Hyyppä et. all 2012, Li et. all 2023). Despite the diversity of laser tools, they are one of the fastest-growing state-of-the-art technologies that are constantly being implemented in new areas of application (Candela et. all 2023, Chavan et. all 2023, Guilhot and Ribes-Pleguezuelo, 2019, Wu et. all 2020, Zhang et. all 2021). The fiber laser engraving is an advanced and modern technology, used for its exceptional capabilities in intricately etching designs onto both flat and uneven surfaces (Lian et. all 2021). Within the transformative technology of Industry 4.0 and Industry 5.0, where automation, connectivity, and data exchange redefine manufacturing processes, laser engraving assumes an important role in achieving unparalleled precision and efficiency in material processing (Briken et. all, 2021, Kaasinen et. all, 2022, Kozlovska et. all 2021, Rahmani et. all 2023). Beyond its technical prowess, laser engraving embodies a unique synergy between human creativity and technological innovation, offering personalized options and intricate designs that reflect the collaborative efforts of human factors and automated systems (Abdulazeem and Hu, 2023, Dovramadjiev et. all, 2023). Recognizing the intrinsic interplay between laser technology and human factors becomes imperative for fully leveraging its potential in the Industry 4.0 era. By exploring this dynamic intersection, this research endeavor not only enhances our understanding of laser engraving's capabilities but also underscores the importance of human-centric considerations in optimizing and maintaining these cutting-edge technologies (Girdu and Gheorghe, 2023, Jansen et. all 2019, Liu and Chang 2023). Through a nuanced examination of laser technology and human factors, this study aims to propel advancements in material processing and manufacturing efficiency, fostering a harmonious integration of technology and human ingenuity in the industrial field.

Industry and business are closely related, and management also has a direct influence on technology and innovation (Carpitella et. all, 2018, Mulaomerovic and Wang, 2023, Murzova and Dimitrakieva, 2009, Murzova and Zlateva, 2023). From an economic standpoint, the integration of laser technology into manufacturing processes presents notable advantages (Fedin et. all 2000, Levy, 2010). The precision and efficiency offered by fiber lasers reduce material wastage and production time, leading to cost savings for manufacturers. The versatility of laser engraving allows for the customization of products, catering to diverse consumer preferences and potentially increasing market competitiveness. With reduced operational costs and enhanced product appeal, businesses can capitalize on the economic benefits of adopting fiber laser engraving technology.

Laser engraving is a technology suitable for objects with diverse shapes and relief (Genna et. all, 2020, Khan et. all 2021, Pallarés-Aldeiturriaga et. all 2021). It involves the removal of the top surface of the material through a precisely directed laser beam. This technology provides a wide range of design and personalization possibilities. The results of laser engraving depend on several key factors, such as the composition and properties of the material, the power of the laser beam, and the speed and intensity of the process. In this context, the article explores the specifics of engraving with a fiber laser, which is highly effective in processing materials such as leather, metal, and composite panels (ABS). The aim of the article is to investigate the impact of irregular shapes and relief on objects concerning the laser beam's coverage. For this purpose, objects with flat and oval shapes were engraved.

2. MATERIALS AND METHODS

A distinctive feature of laser engraving is its applicability to objects of various shapes and sizes, making the technology extremely versatile across different industries (Murzin and Stiglbrunner, 2024) . The maximum dimensions of the object and the printing area that the machine can cover vary depending on the specific model and technical specifications of the laser. In this case, the machine used for engraving is the Bodor BML-20FP Fiber Laser with a maximum printing area of 10x10 cm and a maximum object height of 10 cm. This laser is suitable for processing metal, leather, rubber, and composite materials, specifically designed for engraving. It is used in the production of company seals, branding of promotional materials such as pens, lighters, USB drives, etc. Additionally, it can be used to brand plaques, belts, and other items made of genuine leather. (Fig. 1)

Fig. 1. Methodology of laser engraving process

3. RESULTS

During the preparation process for engraving, the laser provides the opportunity for exceptional accuracy and precision in positioning through laser markers that outline the print area according to the specified file. This way, the optimal printing field on the object can be determined (Fig. 1).

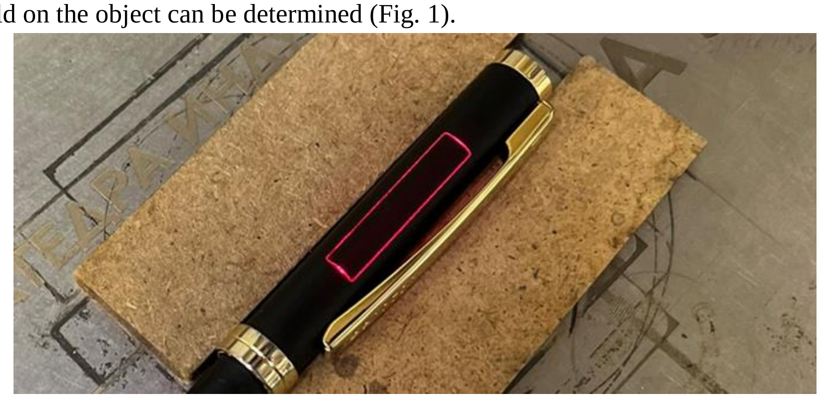

Fig. 2. Marking the print field according to the desired size and position

When engraving on flat and uneven surfaces, as well as on objects with irregular shapes, it is necessary to consider the optimal print field so that the laser remains directed in the same plane throughout the process. Applying the laser beam at different heights can lead to changes in the engraving intensity in the same area, resulting from variations in the object's relief and the deviation of the beam from its optimal values. If the beam passes through different heights, it is at different distances from the marking point, leading to varying engraving intensities. This means that at the closest point of engraving, the result will be dense and focused, while at the farthest point, it will disperse and reduce its intensity (Fig. 3).

Fig. 3. Engraving on identical objects with a change in the marking field size

On the left, the print is condensed in one plane, making it dense and clear, while on the right, the edges disperse, and the image becomes unclear.

The system settings requirements vary depending on the material, and the correct configuration leads to optimal results. The main variables are "speed," "frequency," and "intensity," which are tested when processing each new material, relying on previous practical experience. Changing these settings produces different end results when engraving the same object. The result can be more saturated or more delicate. Different intensity of filling or contour detailing can be selected (Fig. 4).

Fig. 4. Two-layer ABS (Acrylonitrile Butadiene Styrene) sheet suitable for laser engraving

The change in results is visualized for identical objects with different engraving parameters. Despite the limitless creative and personalized possibilities offered by laser engraving, attention to the correct settings is of crucial importance. Improper application can lead to detrimental results and even the destruction of the object, causing unwanted burns or piercing. Therefore, correct configuration and attention to detail are key to achieving successful and high-quality engravings.

4. DISCUSSIONS

Fiber lasers find widespread applications in the industry and metal engraving, where their high precision and efficiency make them a preferred choice. In the medical industry, they are used for marking instruments and manufacturing metal components. They are also applied in electronics, jewelry, and the production of promotional materials.

Fiber lasers are an exceptionally important tool with a broad range of applications in various industries. Their high precision and efficiency make them a key player in modern metalworking, where they are used for engraving and marking with exceptional accuracy. In the medical industry, fiber lasers are applied for marking instruments and manufacturing metal components. In electronics, they provide opportunities for precise cutting and material processing. Jewelry making also benefits from their capabilities for precise engraving and cutting. Additionally, fiber lasers are utilized in the production of promotional materials, combining high efficiency with flexibility.

5. CONCLUSIONS

The technology of fiber lasers plays a crucial role in accelerating and optimizing various manufacturing processes, thereby supporting innovation and competitiveness across different industries. This reflects significant advancements in the precision and efficiency of material production processes.

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